Subject: Laser Safety Program Documentation

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BROOKHAVEN NATIONAL LABORATORY
LASER CONTROLLED AREA
STANDARD OPERATING PROCEDURE (SOP)

This document defines the safety management program for the laser system listed below. All American National Standard Institute (ANSI) Hazard Class 3b and 4 laser systems must be documented, reviewed, and approved through use of this form. Each system must be reviewed annually.

System description: Deep Ultraviolet Free Electron Laser, Experiment End Station
Location: Source Development Laboratory, Building 729, Experiment End Station

LINE MANAGEMENT RESPONSIBILITIES

The Owner/Operator for this laser is listed below. The Owner/Operator is the Line Manager of the system and must ensure that work with this laser conforms to the guidance outlined in this form.

Owner/Operator:

Name: Thomas Tsang *Signature:* *Date:*

AUTHORIZATION

Work with all ANSI Class 3b and 4 laser systems must be planned and documented with this form. Laser system operators must understand and conform to the guidelines contained in this document. This form must be completed, reviewed, and approved before laser operations begin. The following signatures are required.

Chris Weilandics

BNL LSO printed name *Signature* *Date*

Andrew Ackerman

ES&H Coordinator printed name *Signature* *Date*

APPLICABLE LASER OPERATIONS				
x General Operation	x Alignment	x Service/Repair	x Specific Operation	Fiber Optics

ANALYZE THE LASER SYSTEM HAZARDS

LASER SYSTEM CHARACTERISTICS					
Laser Type *(Argon, CO2, etc)*	Wavelengths (nm)	ANSI Class	Maximum Power of Energy/Pulse	Pulse Length	Repetition Rate
1) Seed Laser	800 nm or 400 nm	*IIIb*	10 mJ	0.1-100 psec	10 Hz
2) FEL output (fundamental)	100-266 nm	*IIIb*	100 uJ	0.1-2 psec	2.5 Hz
3) FEL output (harmonics)	2nd an 3rd harmonic of (2) 33-133 nm	*I*	1 uJ	0.1-2psec	2.5 Hz

NOTE: For all of the above systems eye protection must be worn when working with open beams

System by system breakdown:

1) Seed Laser
   purpose: seed the FEL process This can be done by overlapping the seed pulse with the electron bunch in the radiator (direct seeding) or in an undulator prior to the radiator, the modulator (in High Gain Harmonic Generation). May also be used to provide 800 nm light for diagnostics or experiment
   output: Typically 1 mJ pulses are injected into the accelerator; only a portion of this makes it through the apparatus to the FEL output window: the 2 silicon carbide mirrors constituting the periscope after the radiator each have a reflectivity of ~ 40% at the seed wavelength, and the output coupling mirror to the diagnostics is currently a dielectric mirror for 266 nm, so its reflectivity at the seed wavelength is 2 x 4% (reflections from both surfaces). The current energy is thus 2 spots of ~ 6 microjoules each. Operators should be aware however, that changes in the output optics or coupling more energy into the seed will raise that number. The current output parameters are: 1-10 psec pulses at 10 Hz, wavelength ~ 800 nm
   beam paths:
   - from laser room, ~35 meters enclosed (via the RF gun hutch) to seeding table in the accelerator enclosure. From there, into the accelerator and ~ 21 meters enclosed to the output port.
   - Diagnostics inside of the accelerator enclosure. The seed beam may be diverted outside of the beamline for various diagnostics (e.g. electro-optic electron beam profiler, THz

output profiler). These applications are covered in the "SDL Drive and Seed Laser System" SOP.

goggles: use e.g. Kentek GBM 64

controls: neutral density filters located on seed table may be inserted in and retracted from the beam through the control system. Power attenuator located in laser room. Beam shutter (located in the laser room) may be controlled from the control area, the laser room, or the gun hutch. A 633 nm cw alignment beam is permanently set up to be co-aligned with the seed beam.

hazard controls: Entire end station area is an interlocked Laser Controlled Area. Unauthorized entry terminates all beams into the area. This beam is terminated by a shutter at the exit port of the vacuum system. If the shutter fails to close, the power supply to the laser is interrupted.

2) FEL output (fundamental)

purpose: supplied to user experiments and diagnostics

output: 200 μJ max, 1000 -100 nm, 0.2-2 psec pulse width, 2.5 Hz

beam paths Within the vacuum system to the interaction area, or through the exit window onto the optical tables. **goggles:** use e.g. Kentek GBM 64

controls: controlled through electron beam and seed beam parameters.

hazard controls: Entire end station area is an interlocked Laser Controlled Area. Unauthorized entry terminates all beams into the area. This beam terminates by the same shutter/laser power supply reachback that terminates the 800 nm light.

3) FEL output (harmonics)

purpose: supplied to user experiments

output: 500 - 33 nm, 0.2-1psec, 1 μJ, 2.5 Hz

beam paths: originates in the radiator (see diagram) and propagates to the experimental chamber (enclosed path)

goggles: N.A (absorbed in air, and no exposure possible).

controls: controlled through electron beam and seed beam parameters.

hazard controls: enclosed beam in vacuum.

☐ **Cryogen Use: None**

☒ **Chemicals & Compressed Gasses**

- Solvents (methanol, acetone) used for cleaning optics, kept in 1-4 liter quantities . Stored with secondary containment.

☐ **Electrical Hazards**

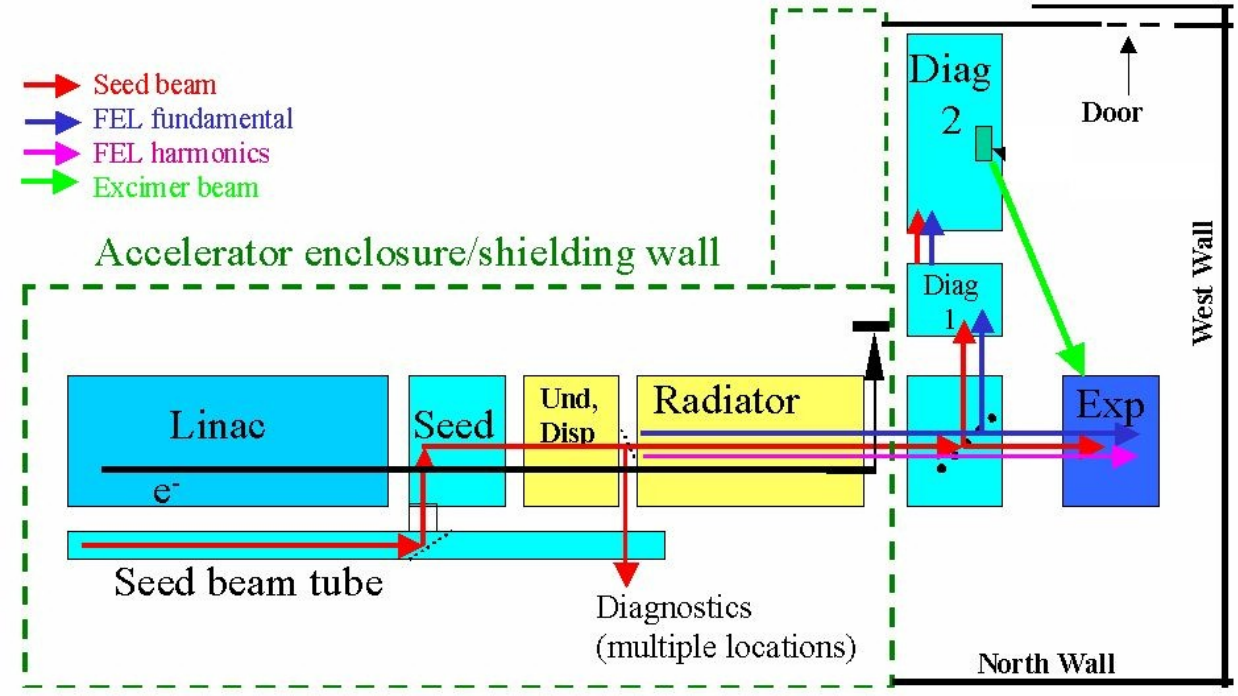
There are no electrical hazards associated directly with the DUVFEL output. Users and operators should of course be aware that this is located in an accelerator laboratory however, and there are electrical hazards associated with that, which are documented in the accelerator standard operating procedures.

☒ **Other Special Equipment**

Standard Diagnostic equipment: oscilloscopes, photodetectors, power meters, autocorrelators, spectrum analyzers, monochromators, streak camera, PC-based data acquisition system, cameras, monitors.

With all optical diagnostics, the operator must exercise special care when working with the optical beams inside the device, as the beams may pose a hazard when misaligned or even during normal operation (e.g. the moving reflection inside a scanning autocorrelator). Read the safety section of the device's manual and wear protective eyewear.(see charts below for proper eyewear for given wavelengths)

Laser System Configuration:
As shown in the diagram below, the seed beam (source #1) propagates in an enclosed pipe parallel to the accelerator on the latter's north side. West of the linac, the beam is deflected into an optical enclosure (box labeled Seed in diagram), where several optics are positioned to couple the beam into the accelerator. The seed beam may be divided in the enclosure and multiple beams introduced into the vacuum system to propagate to the experiment end station. In FEL operation, the seed beam interacts with the electron beam in a short undulator (Und, Disp box) and then propagates to the end of the vacuum line. The electron bunch propagates on through the dispersive section and radiator, and then is deflected by a dipole magnet. The electorn bunch produces the FEL output fundamental and harmonics (sources #2 and #3) inside the radiator section All three sources: seed, fundamental, and harmonics are coupled out of the accelerator enclosure via a periscope comprising 2 mirrors, normally of Silicon Carbide. These steer the beams into the experimental chamber, where they terminate. An insertable mirror located in the output port can divert all or part of the seed and fundamental to the diagnostic tables (Diag1 and Diag2), via enclosed beam tubes. Instrumentation on these tables is used to analyze the output before terminating the beams.



DEVELOP CONTROLS
IDENTIFY ES&H STANDARDS

Recognition, evaluation, and control of laser hazards are governed by the following documents.

American National Standards Institute (ANSI) Standard for Safe Use of Lasers;
(ANSI Z136.1-2000)

Laser Safety Subject Area

Brookhaven National Laboratory Environment Safety and Health Standard: 1.5.3 INTERLOCK SAFETY FOR PROTECTION OF PERSONNEL

ENGINEERING CONTROLS

☒ Beam Enclosures	☐ Protective Housing Interlocks	☒ Other
☐ Beam Stop or Attenuator	☐ Key Controls	
☐ Activation Warning System	☐ Other Interlocks	
☐ Ventilation	☐ Emission Delay	

Engineering Controls Description:

The endstation area is interlocked. If the interlock is tripped by someone opening the entrance door without activating the timed bypass circuit, the lasers in the endstation will terminate emission, and the shutter at the beam output to the diagnostic tables will close. If the shutter fails to close, power to the lasers in the laser room will be interrupted, terminating DUVFEL emission. Inadvertent access to the experimental chamber would vent the accelerator and terminate the beam before exposure would be possible.

ADMINISTRATIVE CONTROLS

☒ Laser Controlled Area ☒ Signs ☒ Labels ☒ Operating Limits

The format and wording of laser signs and labels are mandated by BNL and ANSI standards. Only the standard signs are acceptable. Standard signs are available from the BNL Laser Safety Officer.

All lasers must have a standard label indicating the system's wavelength, power, and ANSI hazard class. Required labels must remain legible and attached. The manufacturer should label commercial systems.

Standard Operating Procedures (SOPs) are required for laser system operation, maintenance (including alignment), and servicing. The SOPs need only contain the information necessary to perform these tasks and identify appropriate control measures including postings and personal protective equipment. The BNL Laser Safety Officer must approve SOPs and copies should be available at the laser installation for reference and field verification of stated control measures.

Administrative Controls Description:

The interlocked enclosure is posted with "Danger" signs, and all lasers and beam tubes are labeled in accordance with the ANSI standard Z136.1. A light shielding wall is in front of the door to the enclosure, and a door stop is positioned so that no light path exists from the enclosure to bystanders when the door is open. The door stop has an emergency pull pin to release it in case this is required for rapid evacuation of the area.

People requiring regular access to the area when laser radiation is present must be trained operators. Visitors must be accompanied by an operator and must wear the mandated eye protection.

It is worth reiterating here a few common sense principles of working with exposed beams:

- always wear eye protection, and make sure that others in the hazard zone are wearing them.
- make sure that reflective jewelry/badges/clothing that might intercept the beam is removed. For example, watches, rings, bracelets, pendulous necklaces. Note that ID badges should not be worn around the neck: they can drop into the beam when you lean over.
- always make all adjustments at the lowest possible intensity
- never insert reflective surfaces into the beam. When inserting an optic, block the beam upstream of the intended insertion, then secure the optic stably in the desired location and orientation, then unblock the beam. When removing an optic, block the beam upstream of the optic before removing it, and be certain of where the new beam path will be with the optic removed..
- always minimize the number of personnel within the hazard zone, and be sure that those who do remain in the area are aware of what you are doing

CONFIGURATION CONTROL

A checklist must be developed for the purpose of verifying the placement and/or status of components that are used to mitigate hazards by configuration control. Examples include any protective housings, beam stops, beam enclosures, and any critical optics *(mirrors or lenses that could misdirect the beam and result in personnel hazard)*. Entries should also be included to ensure placement of required signs and labels and status of interlock verification. Completed checklists must be posted at the laser location. The checklist does not have to be redone unless there has been a system modification, extended shutdown, or change of operations.

See DUV FEL SOP Attachment #1

PERSONAL PROTECTIVE EQUIPMENT

☒ Eye Wear ☐ Skin Protection

Skin Protection: For UV lasers or lasers that may generate incidental UV in excess of maximum permissible exposure (MPE) describe the nature of the hazard and the steps that will be taken to protect against the hazard.

Eye Wear: All laser protective eyewear must be clearly labeled with the optical density and wavelength for which protection is afforded. Eyewear should be stored in a designated sanitary location. Color - coding or other distinctive identification of laser protective eyewear is recommended in multi-laser environments. Eyewear must be routinely checked for cleanliness and lens surface damage.

1. For invisible beams, eye protection against the full beam must be worn at all times unless the beam is fully enclosed.
2. For visible beams, eye protection against the full beam must be worn at all times during gross beam alignment.
3. Where hazardous diffuse reflections are possible, eye protection with an adequate Optical Density for diffuse reflections must be worn within the nominal hazard zone at all times.
4. If you need to operate the laser without wearing eye protection against all wavelengths present, explain the precautions that will be taken to prevent eye injury.

No.	System Name			
1	**Seed Beam**			
2	**DUVFEL output (fundamental)**			
3	**DUVFEL output (harmonics)**			
Laser & Eyewear Parameters				
ANSI Z136.1 Class		I	IIIb	IIIb
Wavelength [nm]		~89, 133	~266	~800
Intra-Beam OD Required				
single shot		NA	1	5
0.25 s		NA	1(single shot)	1
10 s		NA	2	2
600 s diffuse				

EYE WEAR REQUIREMENTS					
Laser System Hazard	Wavelength (nm)	Calculated Intra-beam Optical Density	Diffuse Optical Density*	NHZ** (meters)	Appropriate Eye Wear***
seed laser	800 , 400	5	2	2	Kentek GBM 64
DUVFEL output (fundamental)	100-266	1	0	0	Kentek GBM 64
DUVFEL output (harmonics)	33-133	NA	NA	NA	NA

* Diffuse ODs are calculated assuming a 600 second exposure, a viewing distance of 20 cm, perfect reflectivity, and viewing normal to the surface. The ODs required can decrease for more typical conditions in the laboratory.

**The Nominal Hazard Zone is that zone or distance inside which exists a hazard to the eye from a diffuse reflection (as well as direct or specularly reflected light) for the time specified, in this case, 600 seconds (10 minutes).

***Specified eyewear may not be the only possible option, but represents an approved choice; depending on other laser hazards present in the lab, other eyewear may be acceptable provided the optical densities are equivalent or greater than those required.

EYE WEAR SPECIFICATIONS		
Laser System Eyewear Identification	Wavelengths	Optical Density
Kentek GBM 64	190-520 520-532 750-850 850-1080	9+ 7+ 5+ 7+
Laser Vision L648	633 647-676	2-3 3+

TRAINING

LASER SAFETY TRAINING

Laser Operators must complete sufficient training to assure that they can identify and control the risks presented by the laser systems they use. Owners/Operators and Qualified Laser Operators must complete the awareness level BNL World Wide Web based training course (TQ-LASER) every two years.

Qualified Laser Operators must also complete system-specific orientation with the system owner/operator. **System-specific training must be documented with a checklist that includes**

- Trainee name and signature
- Owner/Operator signature
- Date
- Brief list of topics covered e.g.
  - Review of SOPs;
  - Review of working procedures, and other program specific documentation.

All laser safety training must be repeated every two years.

Procedural Considerations

1. To reduce accidental reflections, watches, rings, dangling badges, necklaces, reflective jewelry are taken off before any alignment activities begin. Use of non-reflective tools should be considered.
2. When inserting or removing an optic from the beam path, be certain that the beam is blocked upstream of the optic until the optic is secured.
3. Consider having someone present to help with the alignment.
4. All equipment and materials needed are present prior to beginning the alignment
5. All unnecessary equipment, tools, combustible material (if fire is a possibility) have been removed to minimize the possibility of stray reflections and non-beam accidents.
6. Persons conducting the alignment have been authorized by the RI
7. A NOTICE sign is posted at entrances when temporary laser control areas are setup or unusual conditions warrant additional hazard information be available to personnel wishing to enter the area.

Alignment Methods to be used for this laser

1. There shall be no intentional intrabeam viewing with the eye. (This statement must remain. Do not delete.)
2. Co-axial low power lasers should be used when practical for alignment of the primary beam.
3. Reduce the beam power through the use of ND filters, beam splitters and dumps, or reducing power at the power supply. Avoid the use of high-power settings during alignment as much as is practical.
4. Laser Protective Eyewear shall be worn at all times during the alignment, within the parameters and notes established on the accompanying laser table.
5. The LSO has authorized reduced optical density eyewear to allow the beam spot to be seen. Measures shall be taken and documented to ensure that no stray hazardous specular reflections are present before the lower OD eyewear is worn. A return to the Maximum OD eyewear as listed in the laser table will be made when the alignment is complete. The eyewear is labeled as alignment eyewear and is stored in a different location than the standard laser eyewear for this operation.
6. Skin protection should be worn on the face, hands and arms when aligning at UV wavelengths.
7. Beam Control- the beam is enclosed as much as practical, the shutter is closed as much as practical during course adjustments, optics/optics mounts are secured to the table as much as practical, beam stops are secured to the table or optics mounts.
8. Areas where the beam leaves the horizontal plane shall be labeled.
9. Any stray or unused beams are terminated.
10. Invisible beams are viewed with IR/UV cards, business cards or card stock, craft paper, viewers, 3x5 cards, thermal fax paper, Polaroid film or similar technique. Operators are aware that specular reflections off some of these devices is possible, and that they may smoke or burn.
11. Pulsed lasers are aligned by firing single pulses when practical.

12. No intra-beam viewing is allowed unless specifically evaluated and approved by the LSO/DLSO. Intrabeam viewing is to be avoided by using cameras or fluorescent devices.
13. Normal laser hazard controls shall be restored when the alignment is completed. This includes enclosures, covers, beam blocks/barriers have been replaced, and affected interlocks checked for proper operation.

Training Checklist for this system and area are in NSLS controlled document LS-SDL-0038

DUV FEL SOP Attachment #1

SDL FEL SOP Attachment #1

DUV FEL Configuration Control Checklist

- DUVFEL Beam terminated in experimental chamber or shutter installed
- Postings to Interlocked area (ANSI Danger signs with emission descriptions) displayed
- Nd:YAG, dye, and excimer laser frames secured to optical table
- Nd:YAG fundamental beam dump mounted and secure.
- Nd:YAG second harmonic beam tubes mounted and secure.
- Beam tubes from Excimer to experimental chamber mounted and secure
- Beam tubes from tripled dye laser output to experimental chamber mounted and secure
- beams terminated on Diag 1 and Diag 2
- Emergency Stop button accessible and clearly marked
- Door stop emergency pull-pin properly installed

A completed checklist must be posted at the laser location.

This checklist must be exercised whenever there has been a system modification, extended shutdown, or change of operations.

Completed by:

(Printed Name) (Signature) (Date)

NSLS REVISION & PERIODIC REVIEW LOG	
Document Number:	LS-SDL-0031
Subject:	Laser Safety Program Documentation: DUV-FEL Line Management Responsibilities

> See NSLS Quality Control Coordinator for original revision and review signatures <

REVISION TABLE

Rev	Description	Date
01	Initial release into controlled document system	10/15/03
02	Include walled, interlocked enclosure and additional excimer,YAG and Dye lasers.	04/16/04
03	Comply with new SOP format	09/30/04
04	Laser owner/operator changed. Excimer, YAG, and dye lasers have been removed, these laser systems are no longer at SDL.	05/02/05

PERIODIC REVIEW TABLE

Complete this table to record the completion of periodic reviews for an existing controlled document. A successful periodic review will reveal the existing document is current, correct, and does not require any revision/change.

Document Review Frequency
1 year

Rev	Date	Reviewed By (Print):	Signature: